Detection of surface heterogeneity in eddy covariance data

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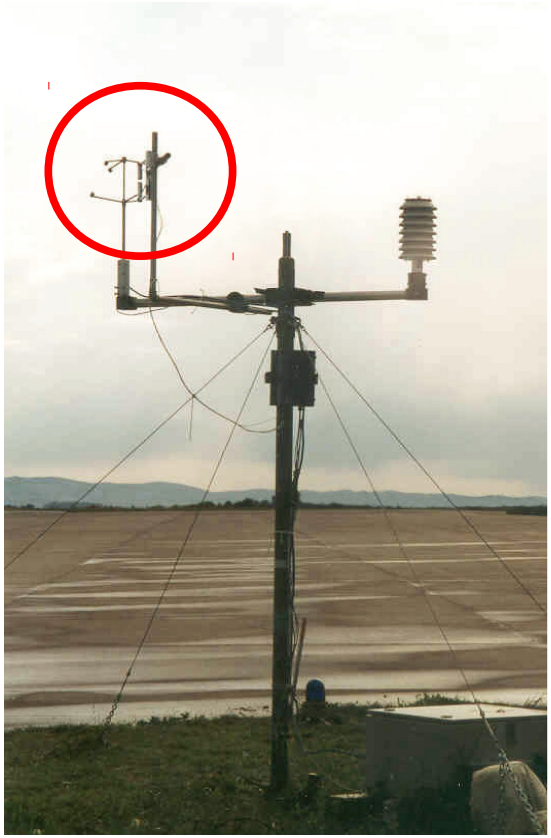
EGU General Assembly, 23 April 2012

Introduction

Eddy covariance method

- Fast sampling of w and transported quantity c
- Vertical turbulent flux via covariance: $\overline{w'c'}$
- Usually half-hour interval
- Here: $\overline{w'\rho'}$ and $\overline{w'T'}$



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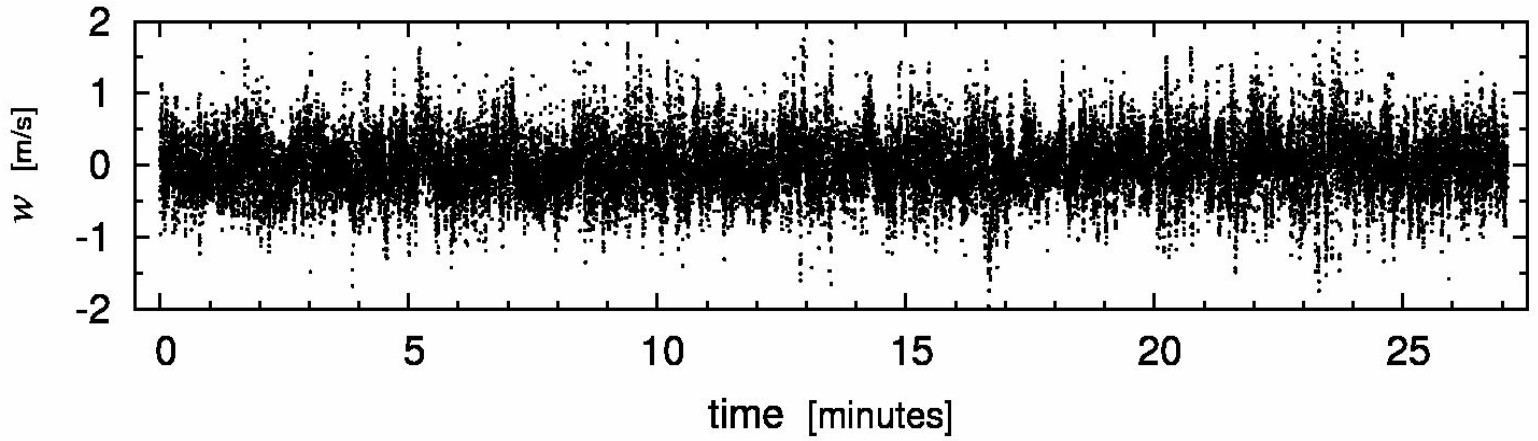

Introduction

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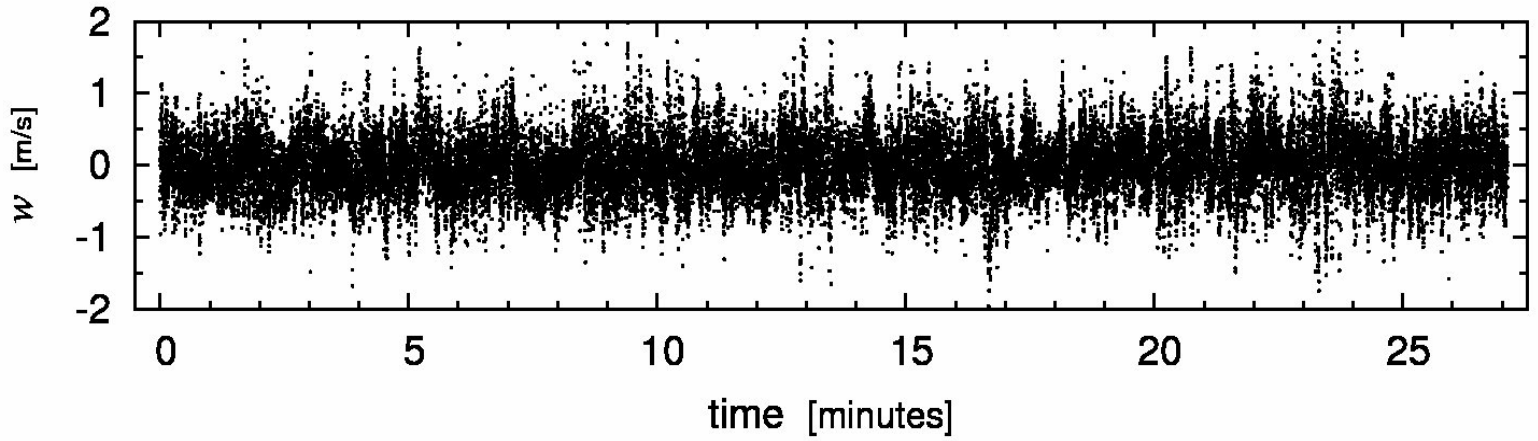
- Here: $\overline{w'\rho'}$ and $\overline{w'T'}$

Interpretation in terms of surface exchange

- Quality issues (ecosystem research: Mahrt 2010; Vickers et al. 2010; Vesala et al. 2008; Foken et al. 2005; ...)
- Here: focus on stationarity



Introduction

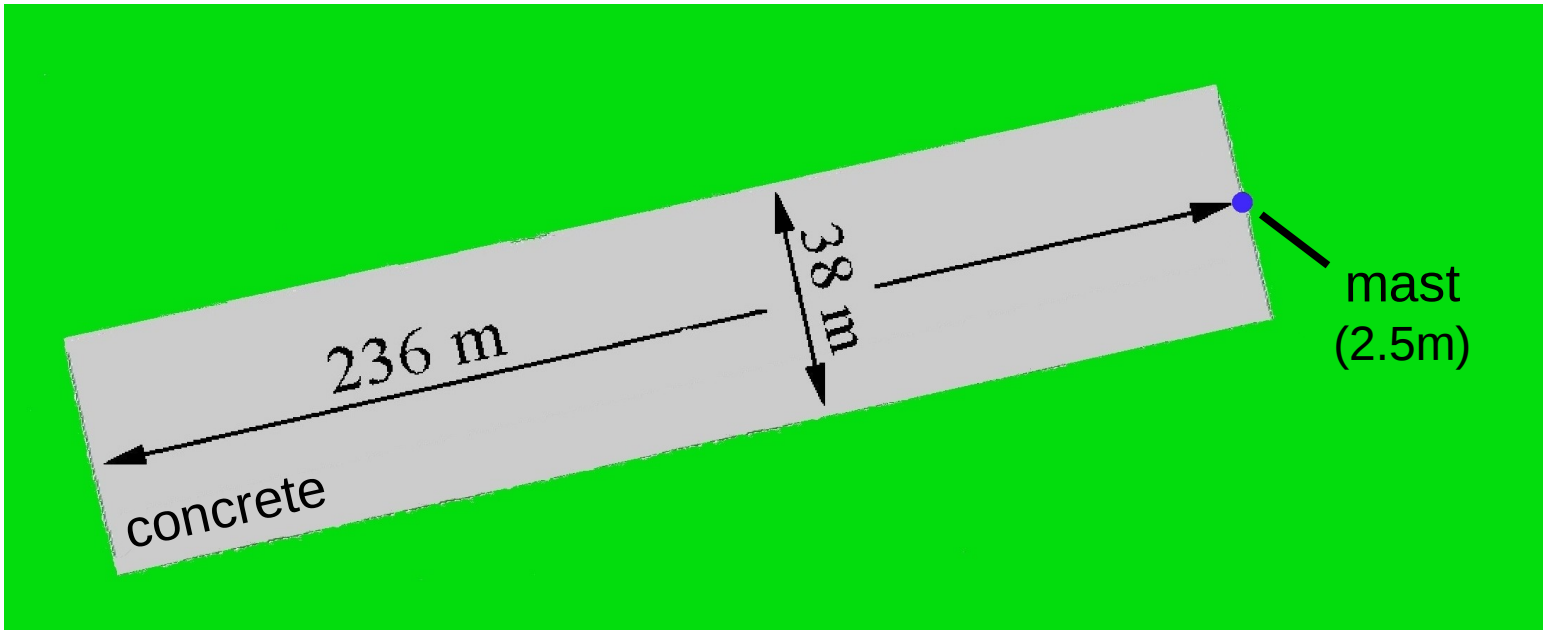
Instationarity

1. Atmospheric trends / variability

Introduction

Instationarity

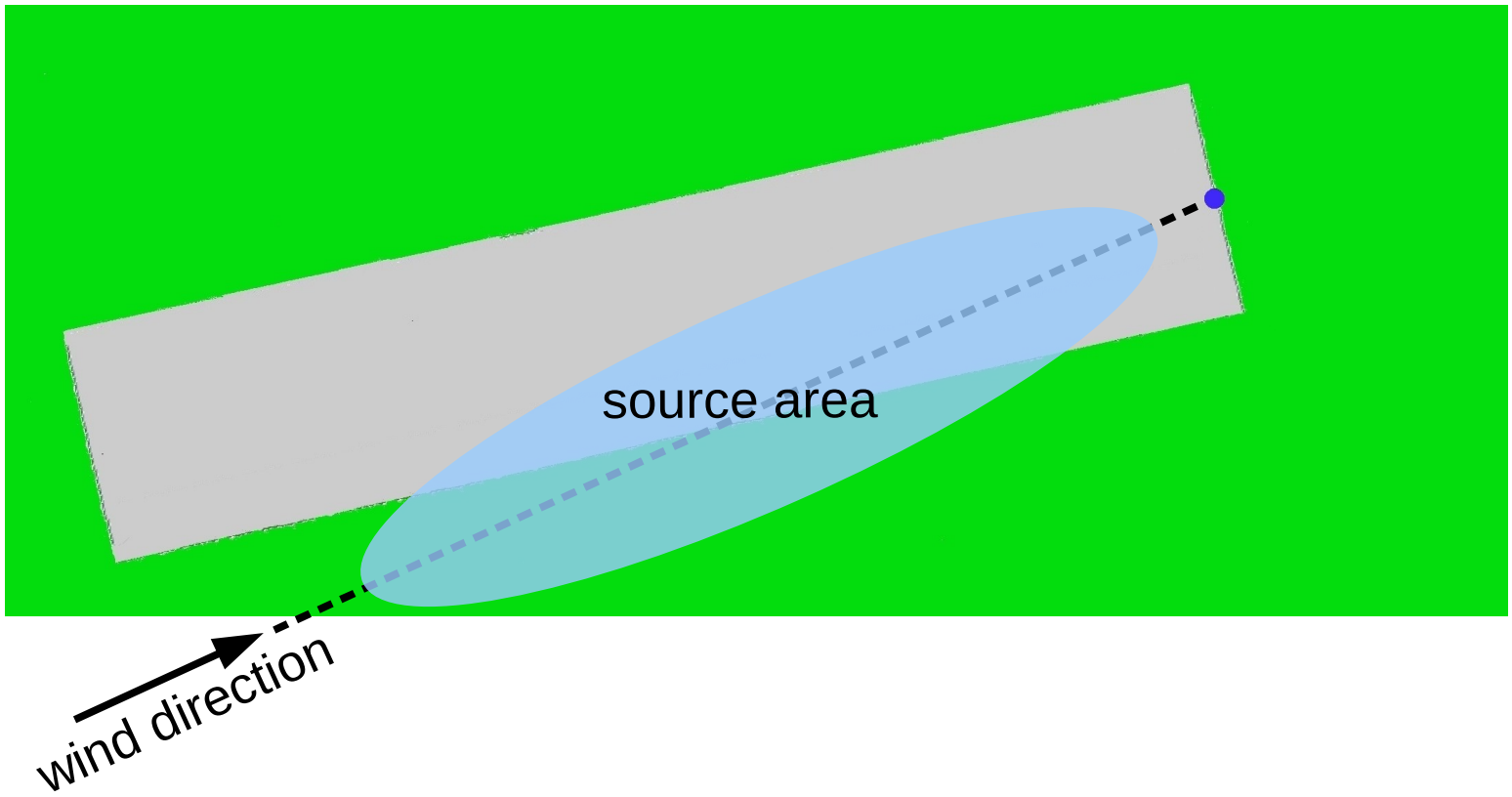
1. Atmospheric trends / variability
2. Surface heterogeneity + wind-direction fluctuations



Introduction

Instationarity

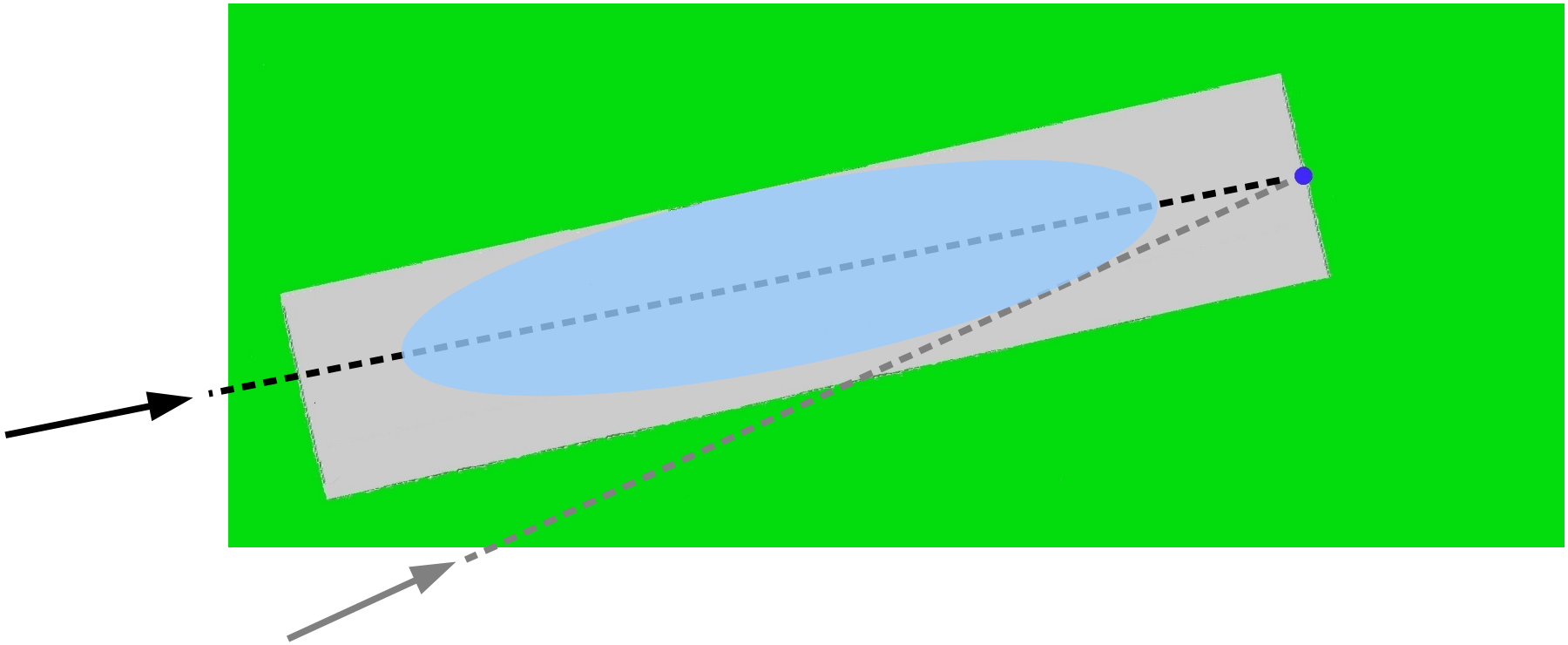
1. Atmospheric trends / variability
2. Surface heterogeneity + wind-direction fluctuations



Introduction

Instationarity

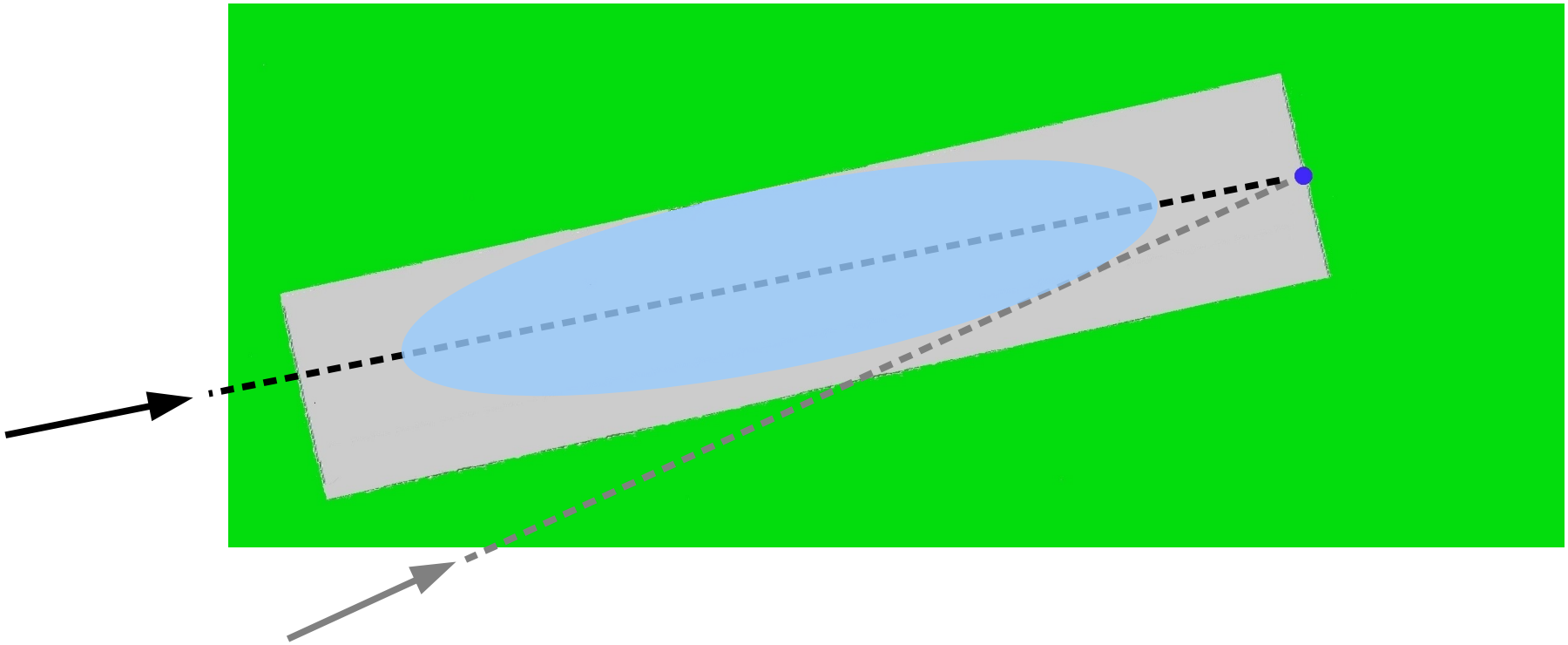
1. Atmospheric trends / variability
2. Surface heterogeneity + wind-direction fluctuations



Introduction

Instationarity

1. Atmospheric trends / variability
2. Surface heterogeneity + wind-direction fluctuations
   (water resources, agriculture, roads, ...)



Introduction

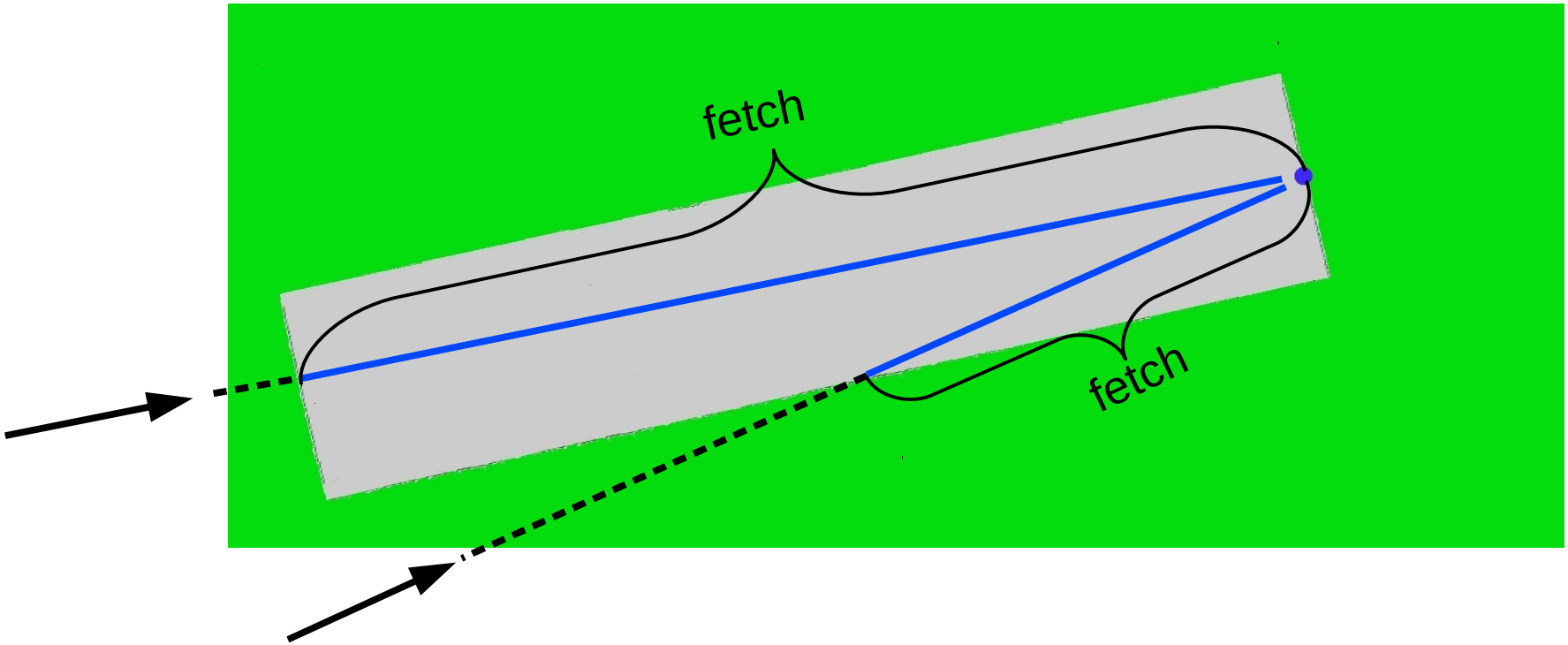
Instationarity

1. Atmospheric trends / variability
2. Surface heterogeneity + wind-direction fluctuations

Presenting a
data-based detection scheme

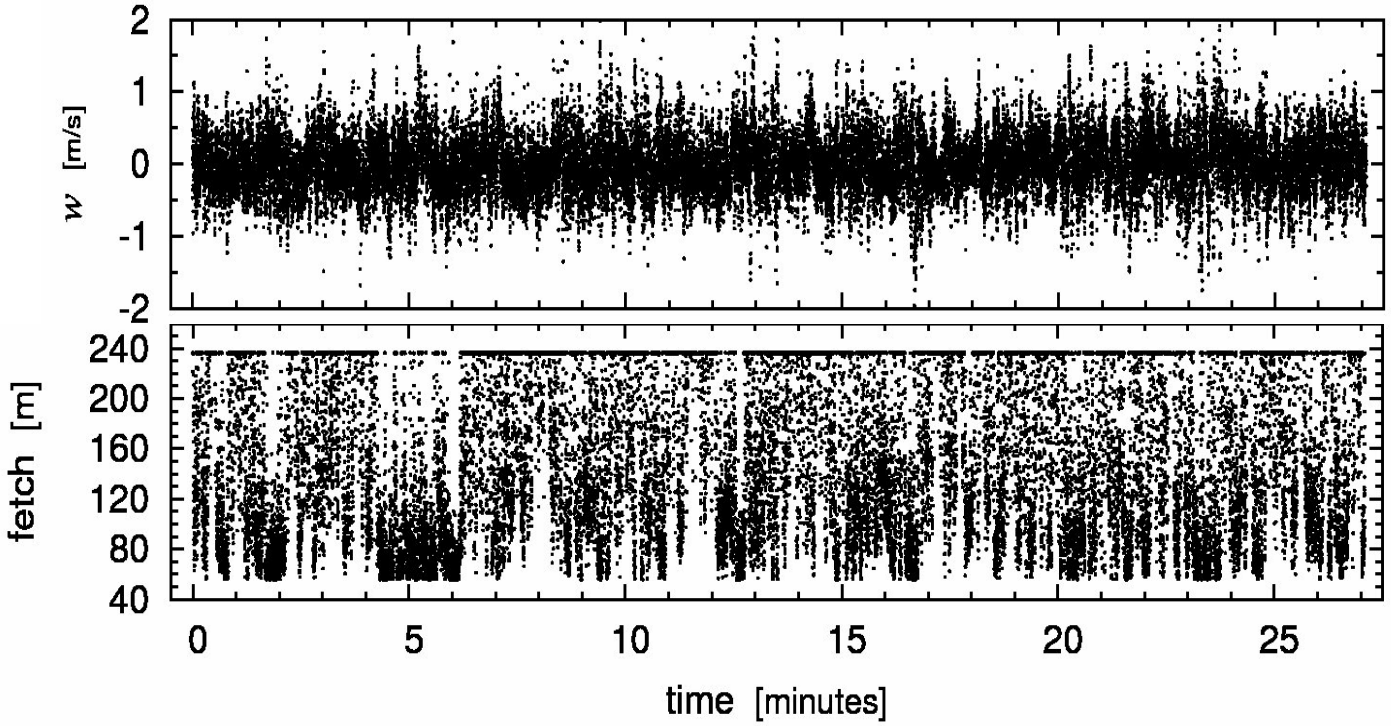
Method

Fetch ~ location of source area



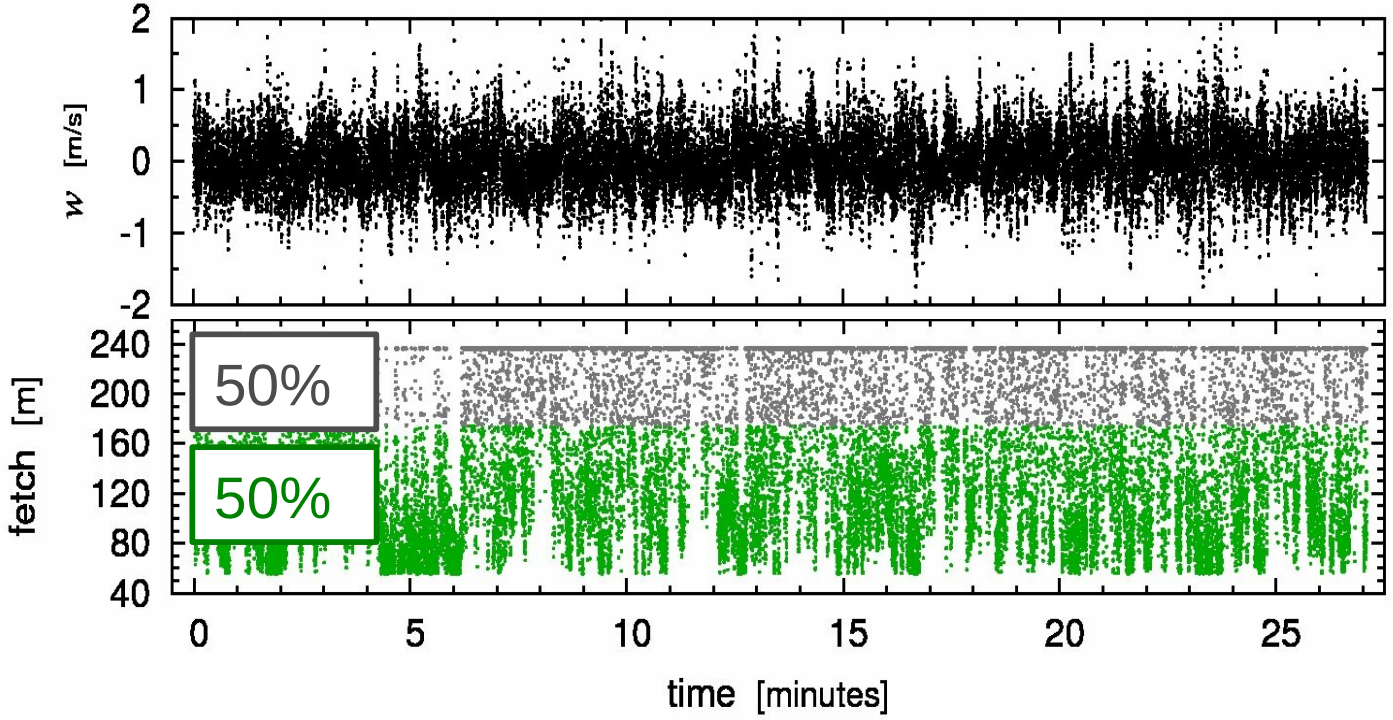
Method

- Association of w and c with fetch



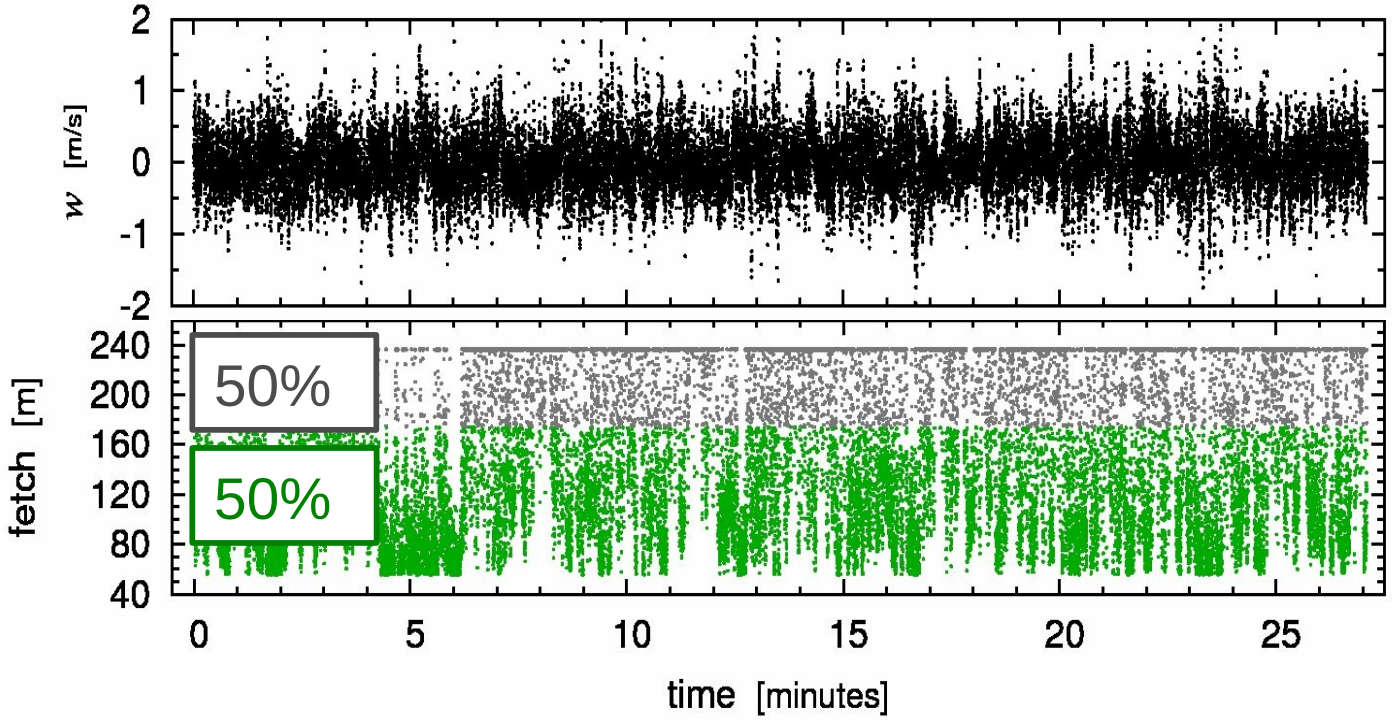
Method

- Association of w and c with fetch
- Median fetch defines two bins



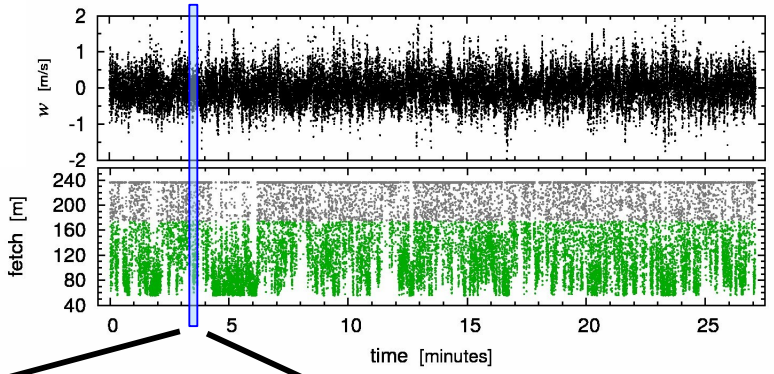
Method

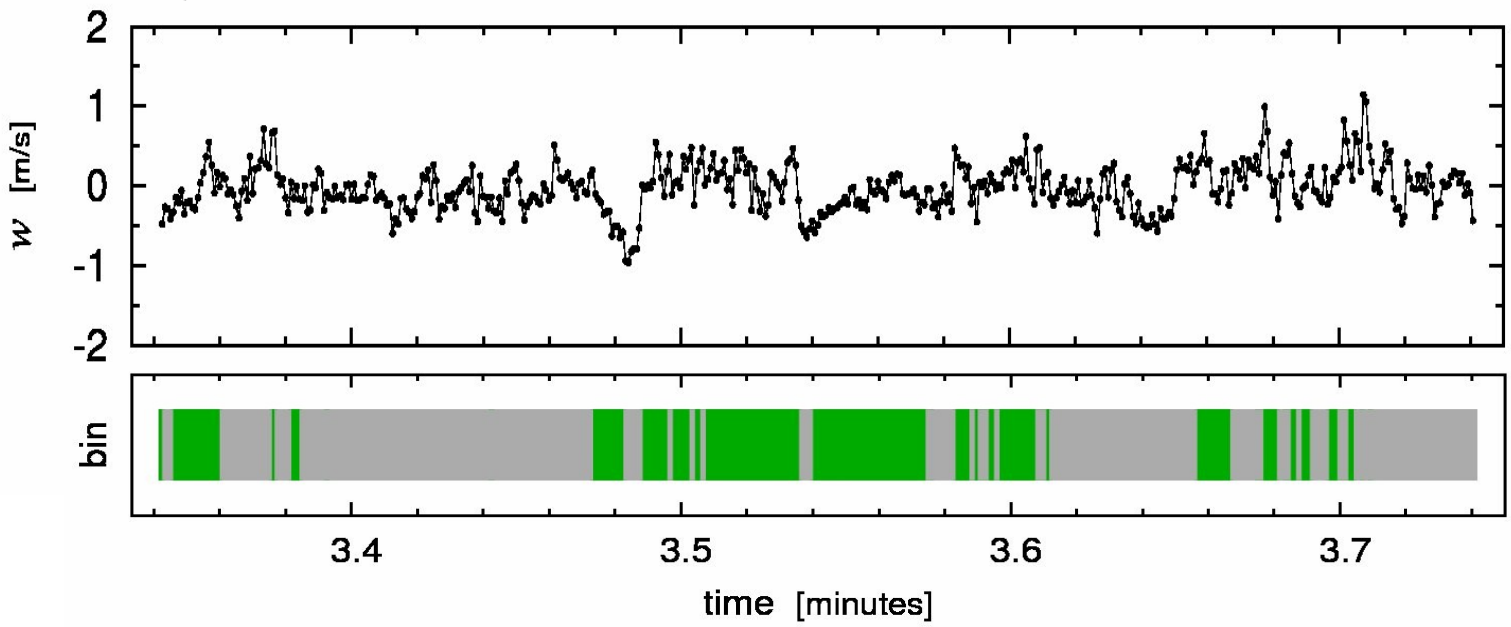
- Association of w and c with fetch
- Median fetch defines two bins
- Separate calculation: $\overline{w'c'}$ and $\overline{w'c'}$



Method

Statistical inference: $\overline{w'c'} - \overline{w'c'}$

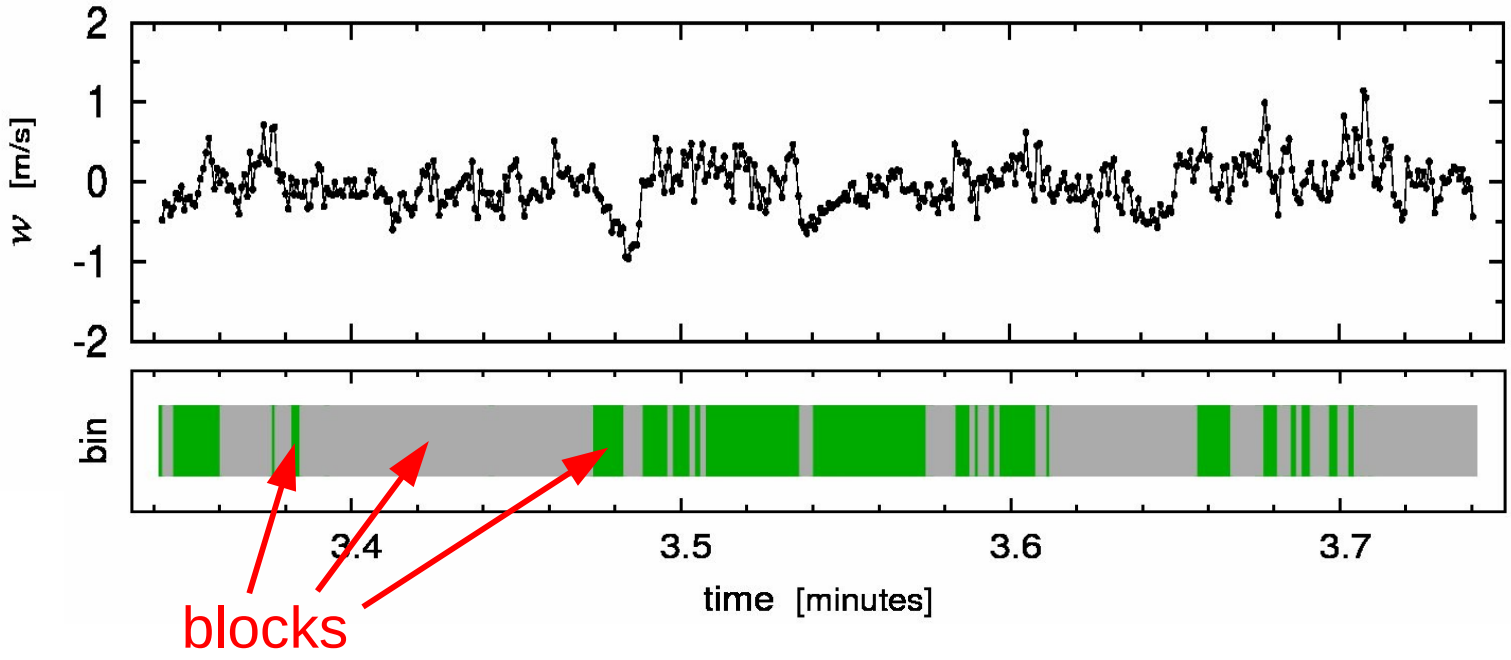




Method

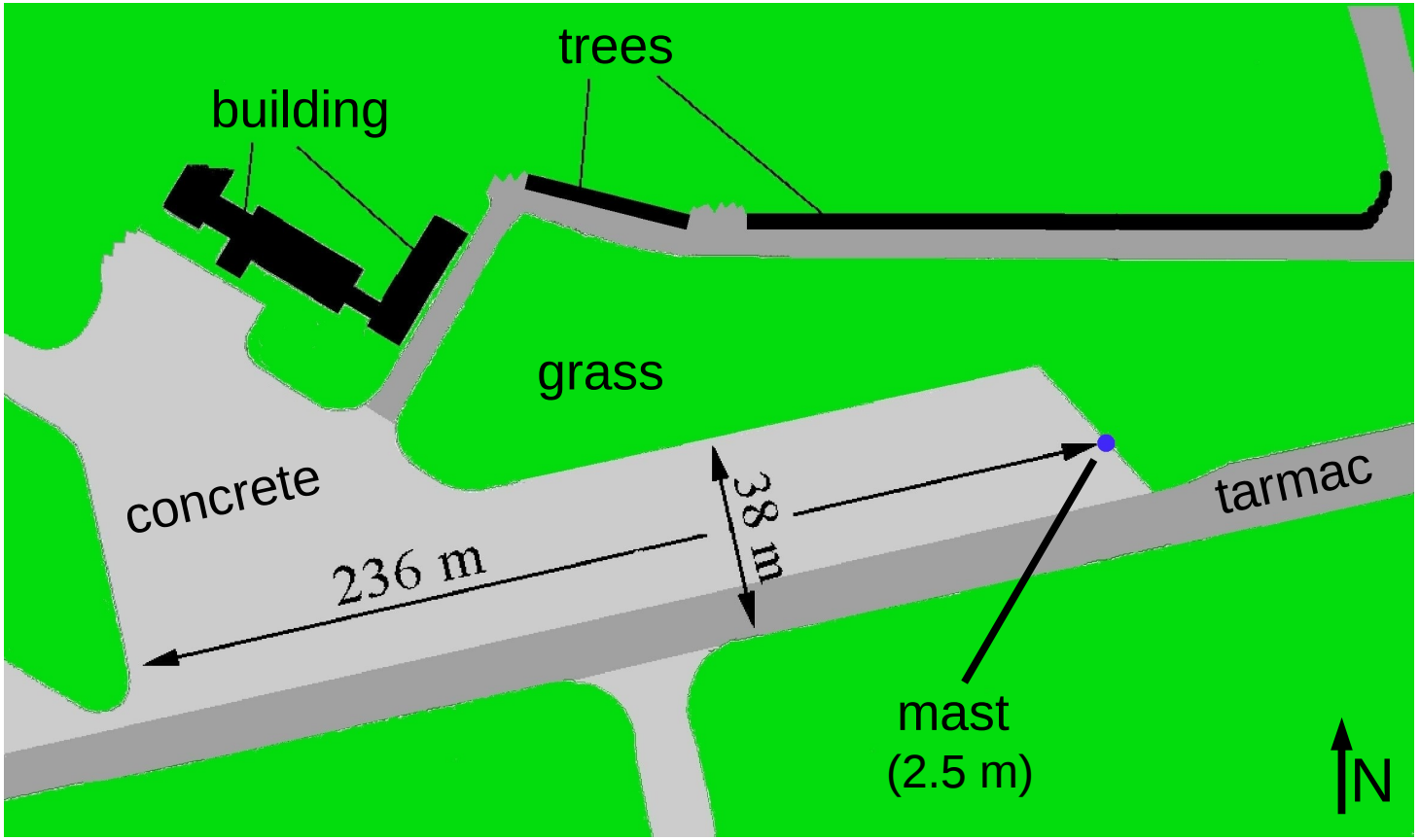
Statistical inference: $\overline{w'c'} - \overline{w'c'}$

- Autocorrelation → keep individual blocks together
- Repeat a lot of times:
  1. Random permutation of „color“
  2. Binning and flux calculation



Campaign

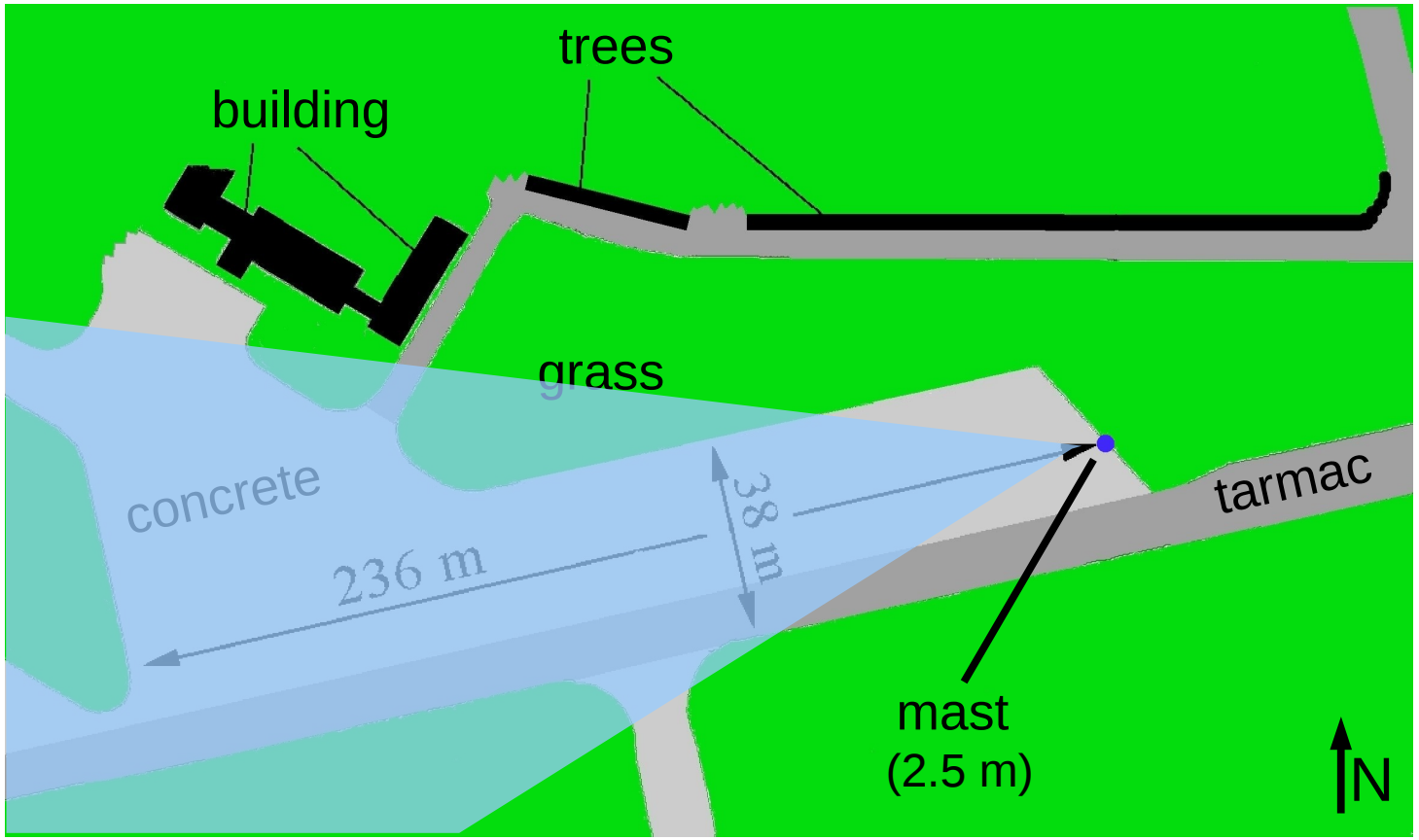
Airport in northern Germany



Campaign

Airport in northern Germany

- Acceptance sector → 40 half-hour data sets
- Spring, daytime, dry conditions

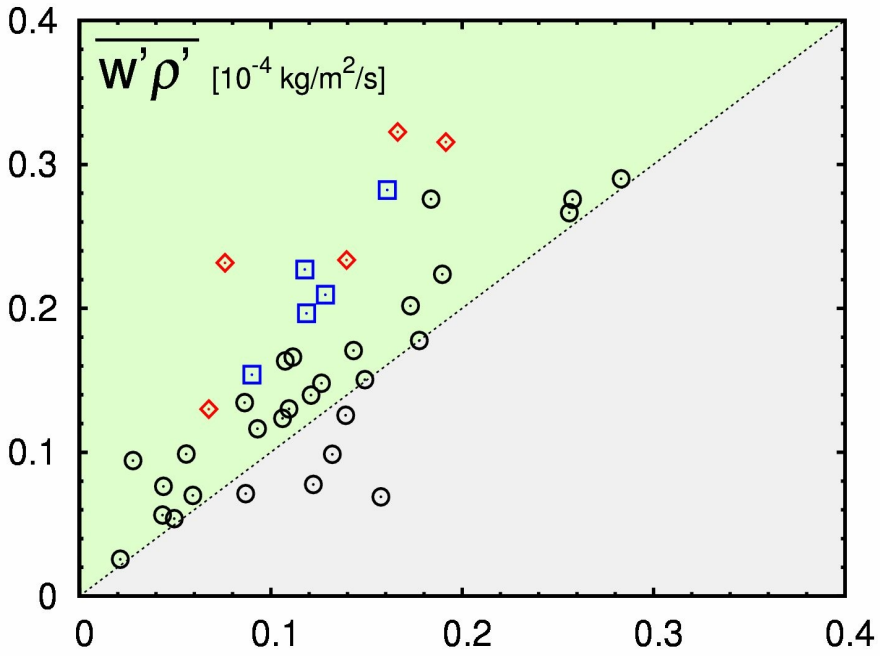


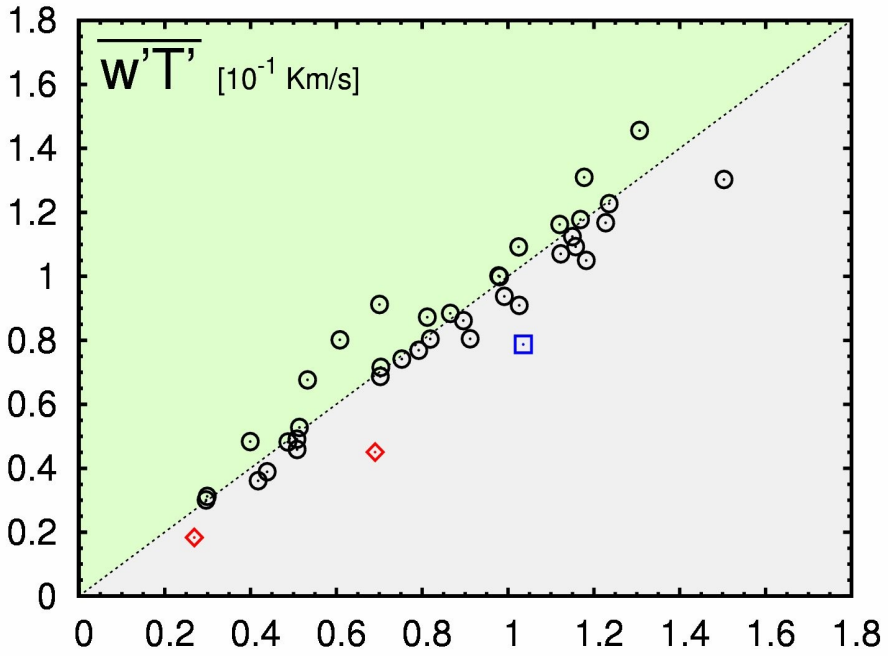
Results

Hypothesis test

- H_0: $\overline{w'c'} = \overline{w'c'}$
- H_1: two sided

◇	p≤0.01
□	0.01<p≤0.05
○	p>0.05





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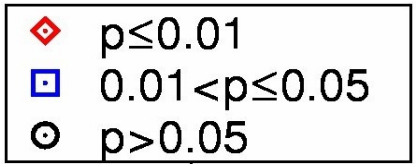
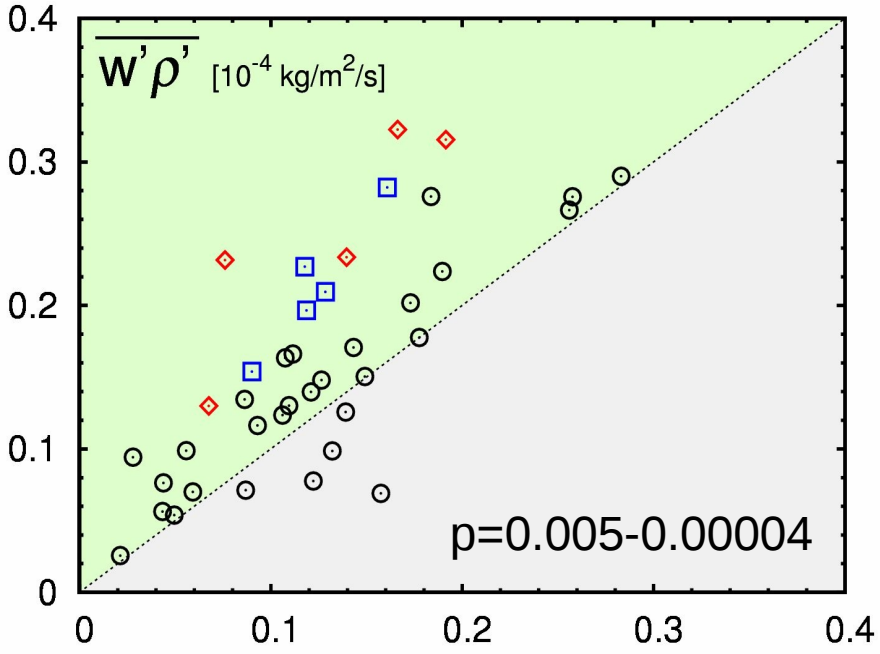
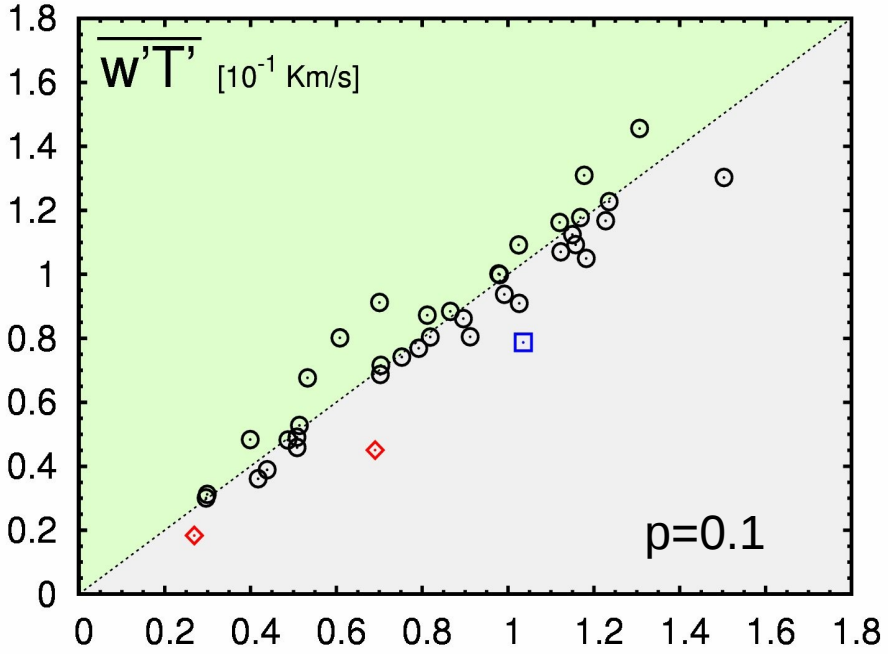


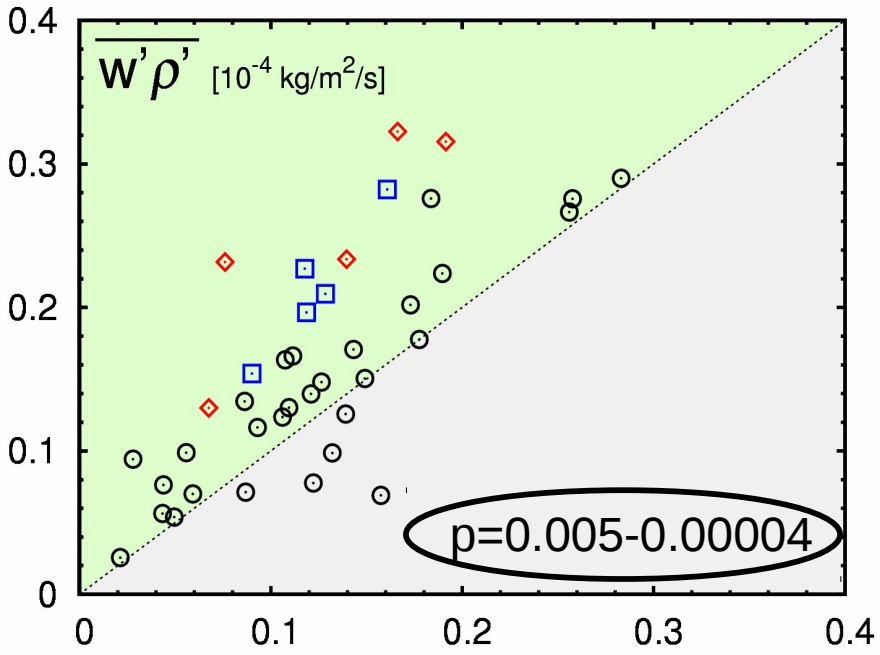
Pooled inference

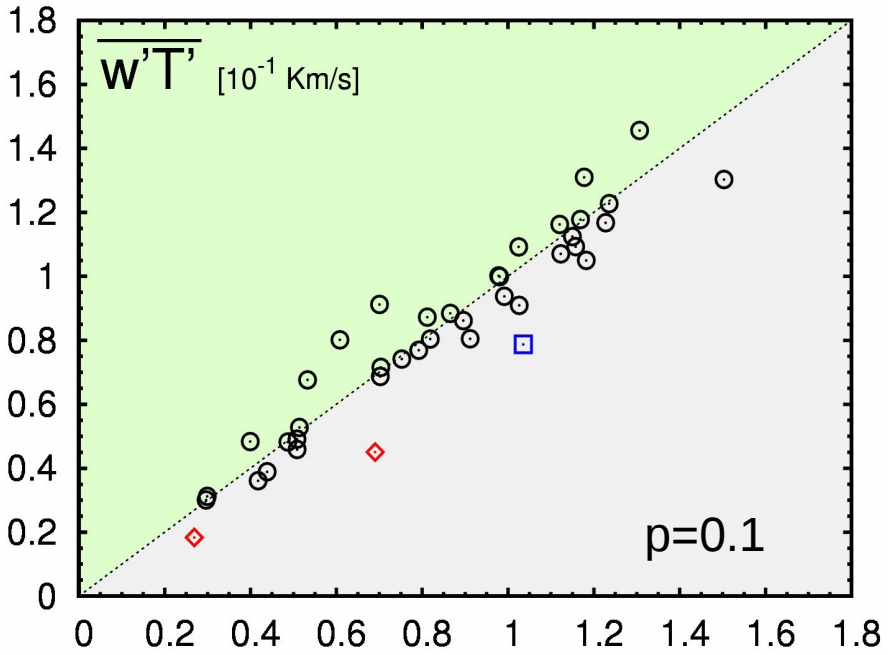
- Weighted least squares (generalized) / weighted bootstrap
- Assumptions ok



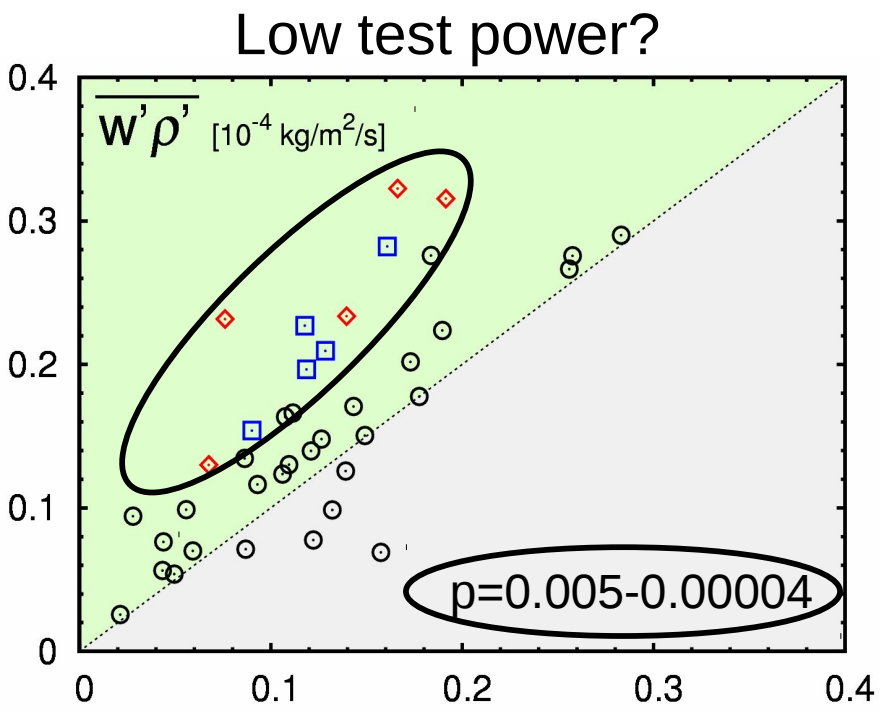


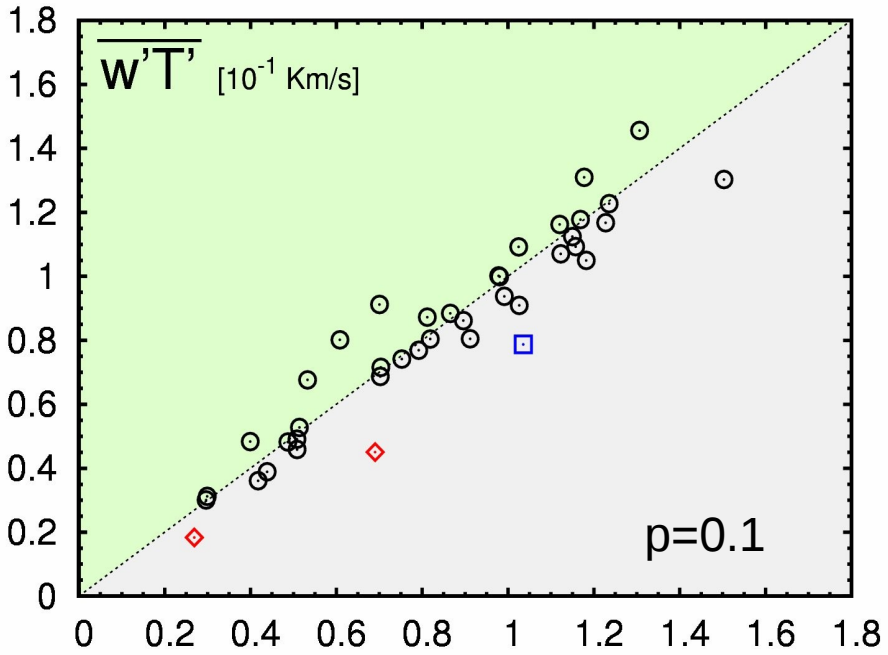
Results


$\overline{w'\rho'}$ [10^{-4} kg/m^2/s]
p=0.005-0.00004
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4

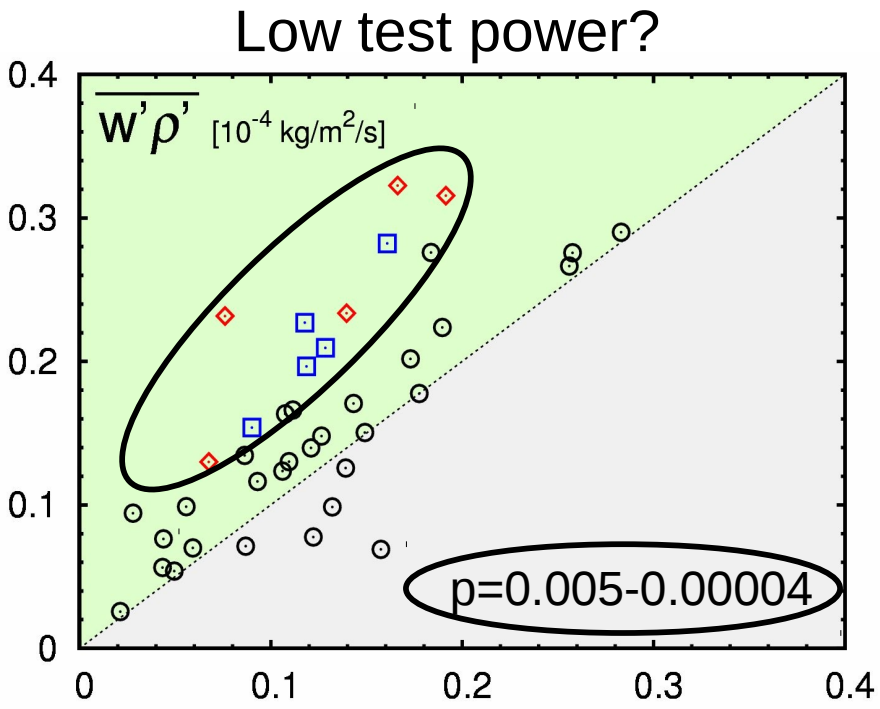

$\overline{w'T'}$ [10^{-1} Km/s]
p=0.1
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8

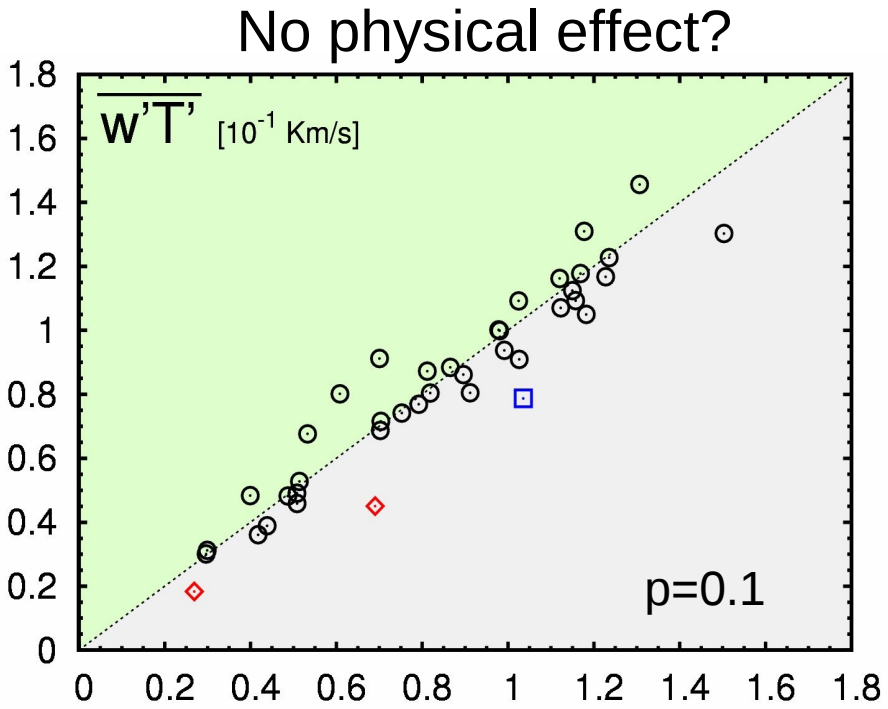
Results


Low test power?
w'ρ' [10^-4 kg/m^2/s]
p=0.005-0.00004
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4


w'T' [10^-1 Km/s]
p=0.1
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8

Results

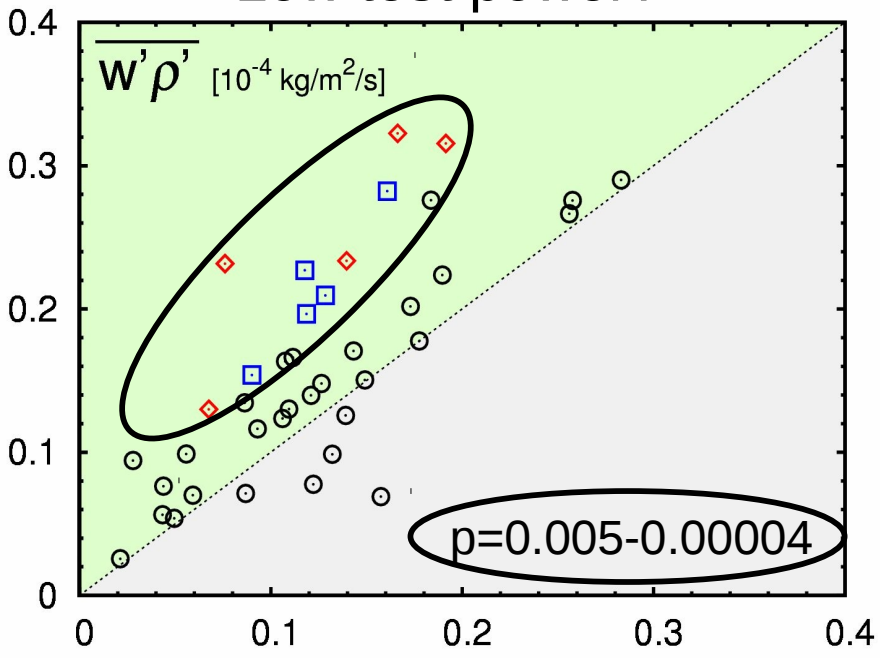

Low test power?
$\overline{w'\rho'}$ [10^{-4} kg/m^2/s]
p=0.005-0.00004
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4


No physical effect?
$\overline{w'T'}$ [10^{-1} Km/s]
p=0.1
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8

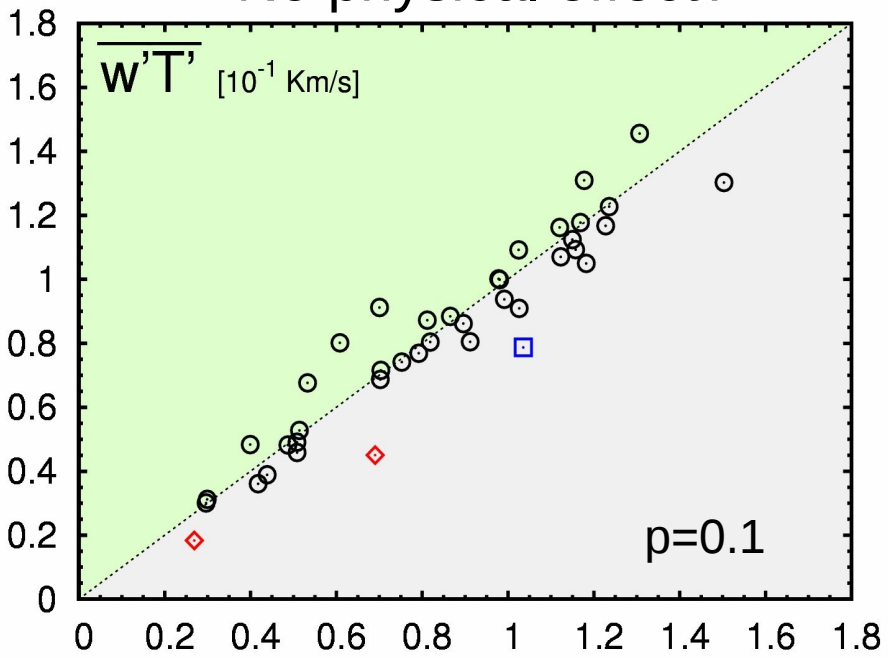
Results

→ Decomposition: $\overline{w'c'} = \sigma_w \cdot \sigma_c \cdot C_{w,c}$

Low test power?



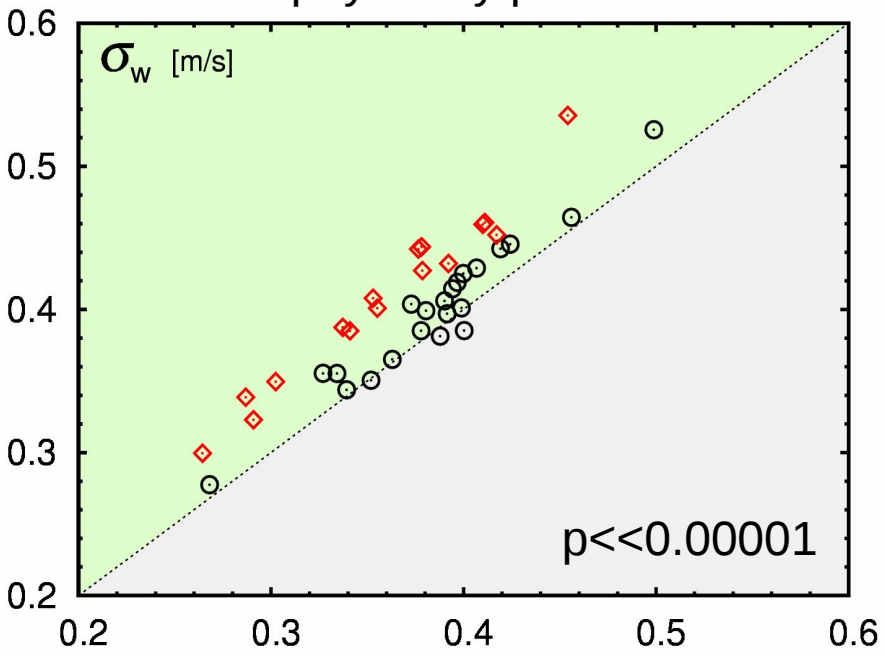
No physical effect?



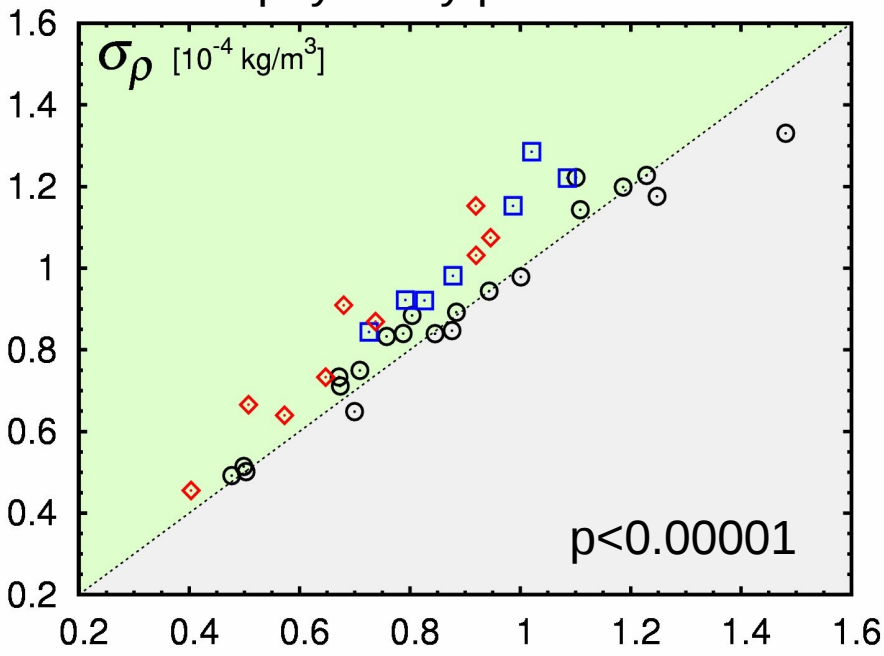
Results

$$\overline{w'\rho'} = \sigma_w \cdot \sigma_\rho \cdot C_{w,\rho}$$

Roughness contrast
→ physically plausible



Evapo-transpiration contrast
→ physically plausible

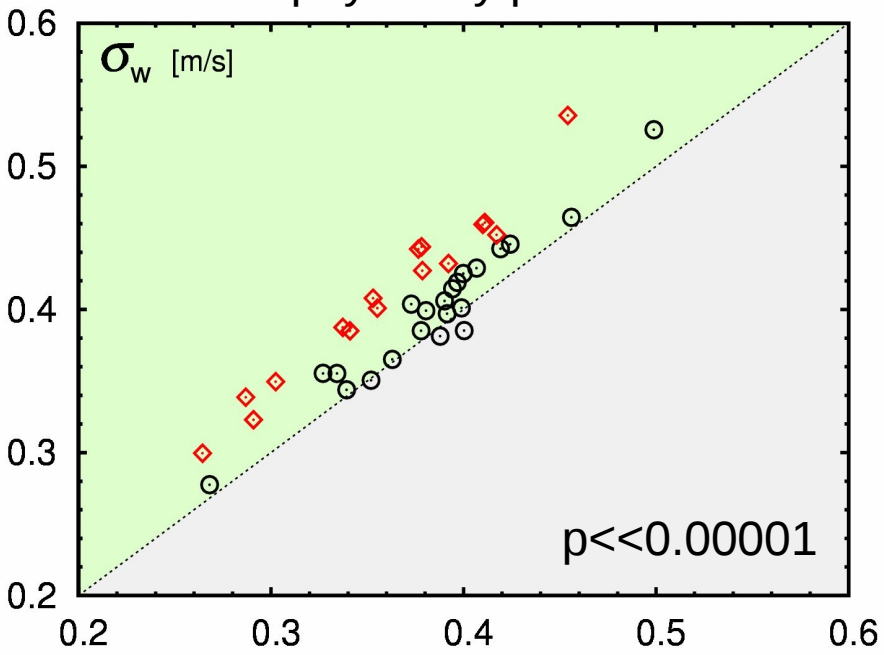


Results

$$\overline{w'\rho'} = \sigma_w \cdot \sigma_\rho \cdot C_{w,\rho}$$

Equal sign

Roughness contrast
→ physically plausible



Evapo-transpiration contrast
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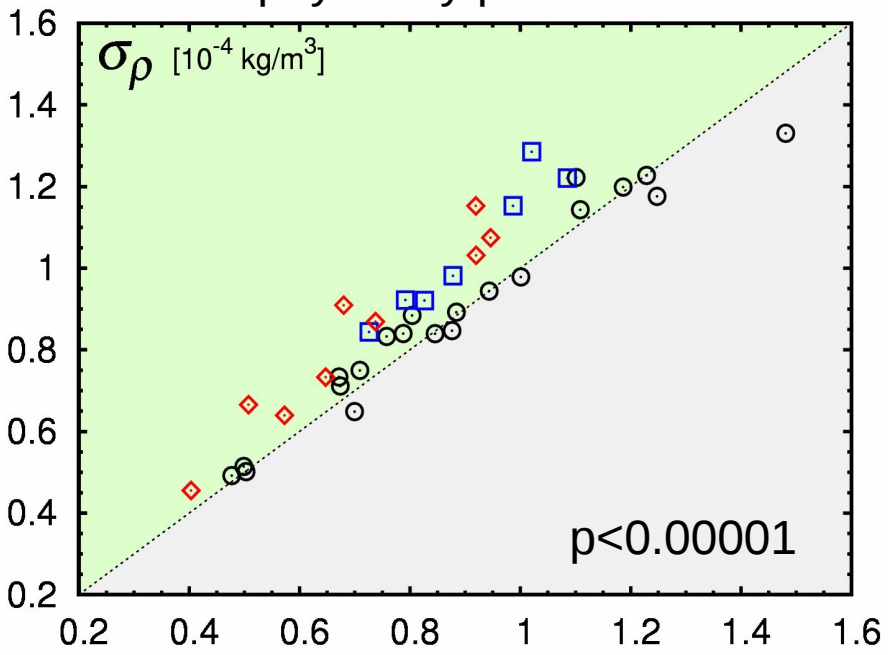


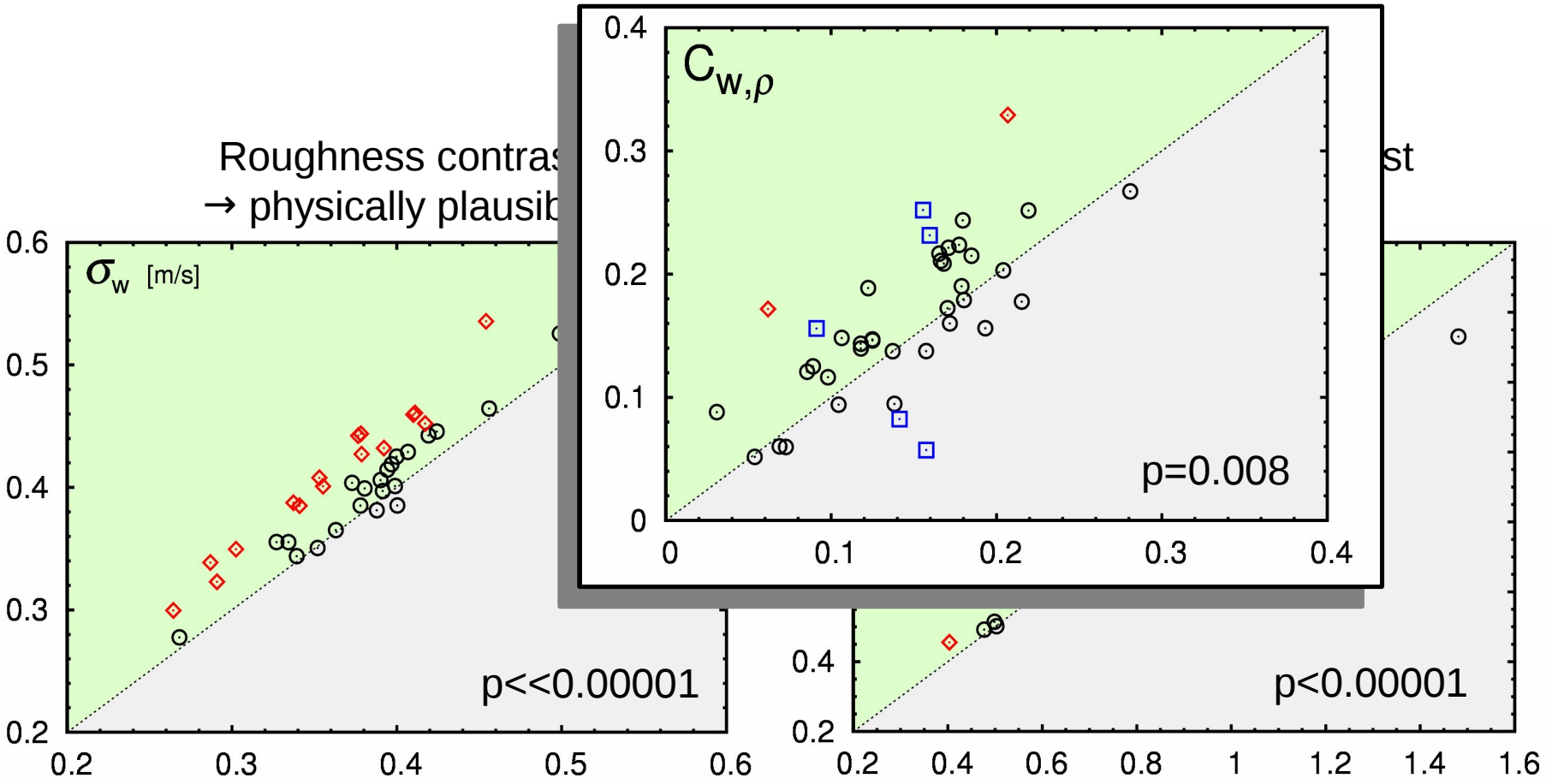
Results

$$\overline{w'\rho'} = \sigma_w \cdot \sigma_\rho \cdot C_{w,\rho}$$

But: scatter from correlation coefficient

Roughness contras → physically plausib

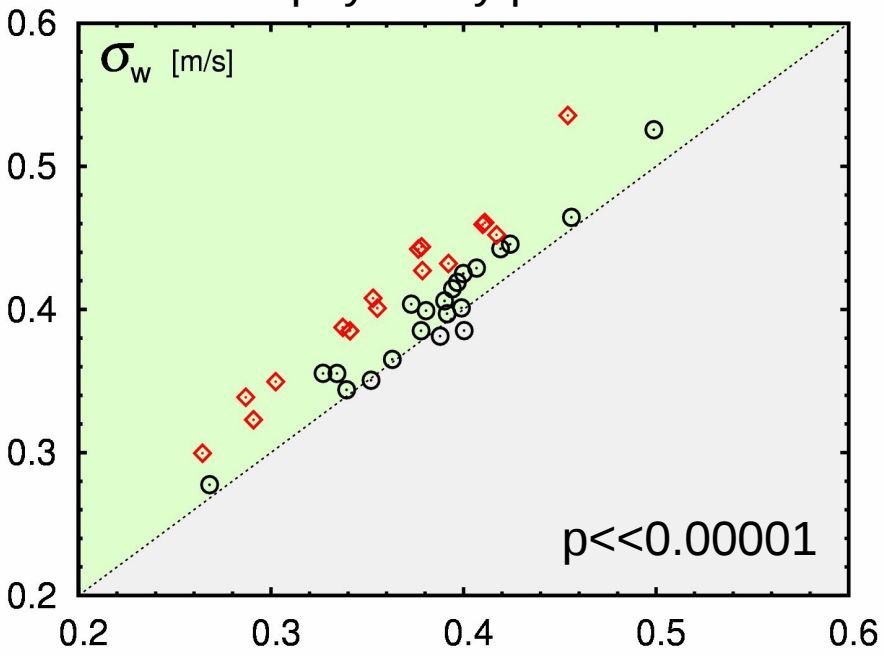
st



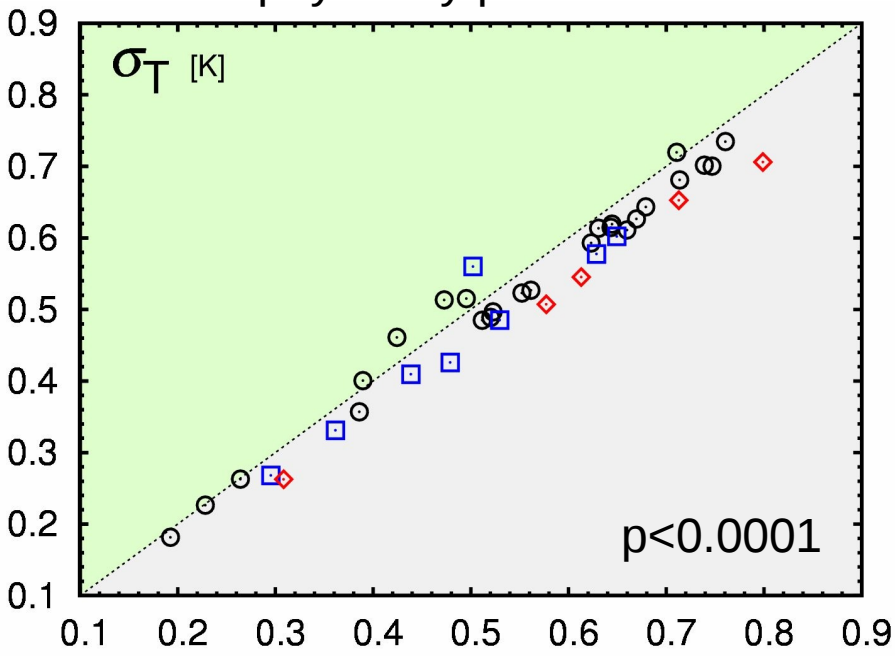
Results

$$\overline{w'T'} = \sigma_w \cdot \sigma_T \cdot C_{w,T}$$

Roughness contrast
→ physically plausible



Temperature contrast
→ physically plausible

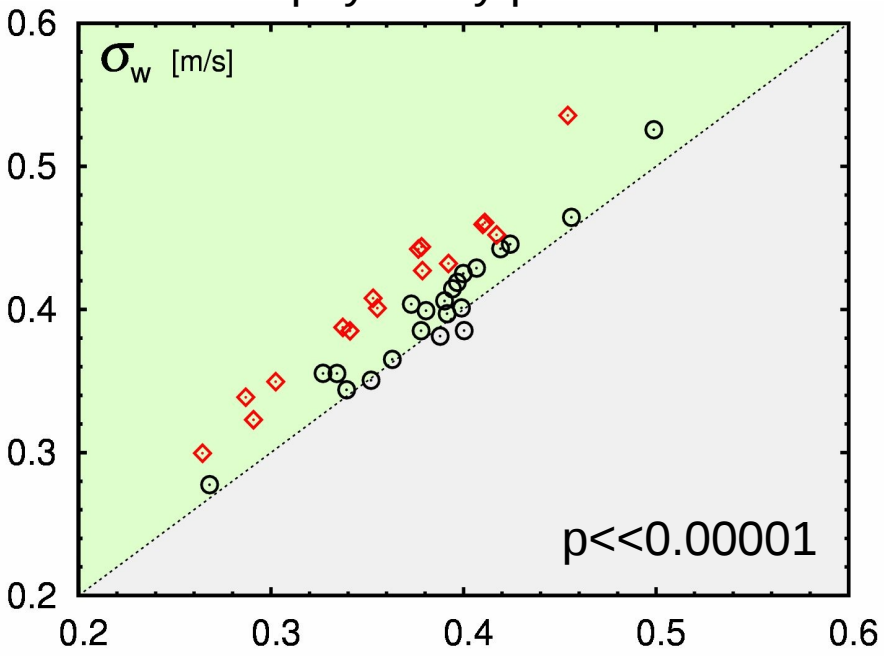


Results

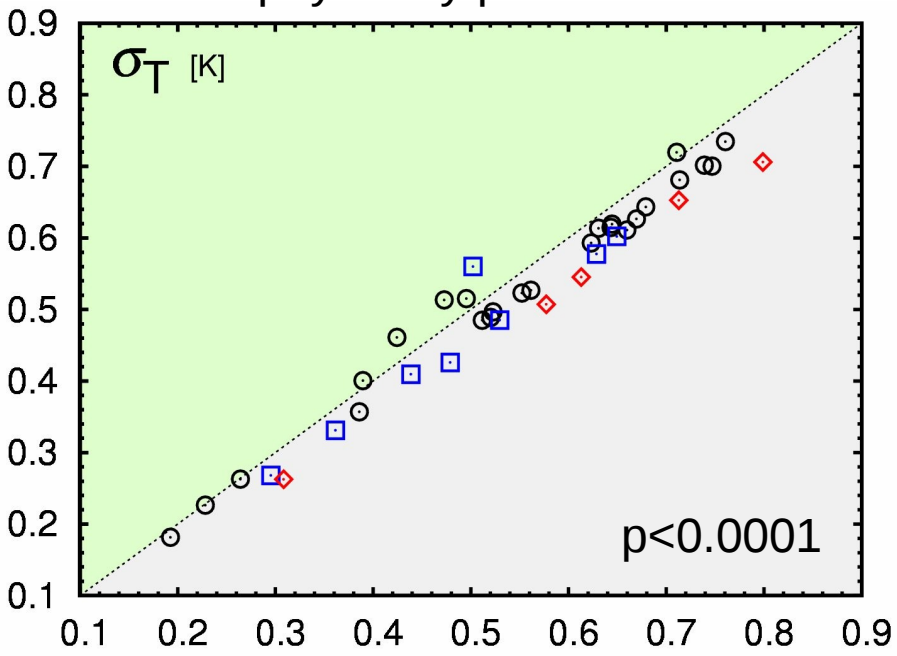
$$\overline{w'T'} = \sigma_w \cdot \sigma_T \cdot C_{w,T}$$

Opposite sign

Roughness contrast
→ physically plausible



Temperature contrast
→ physically plausible

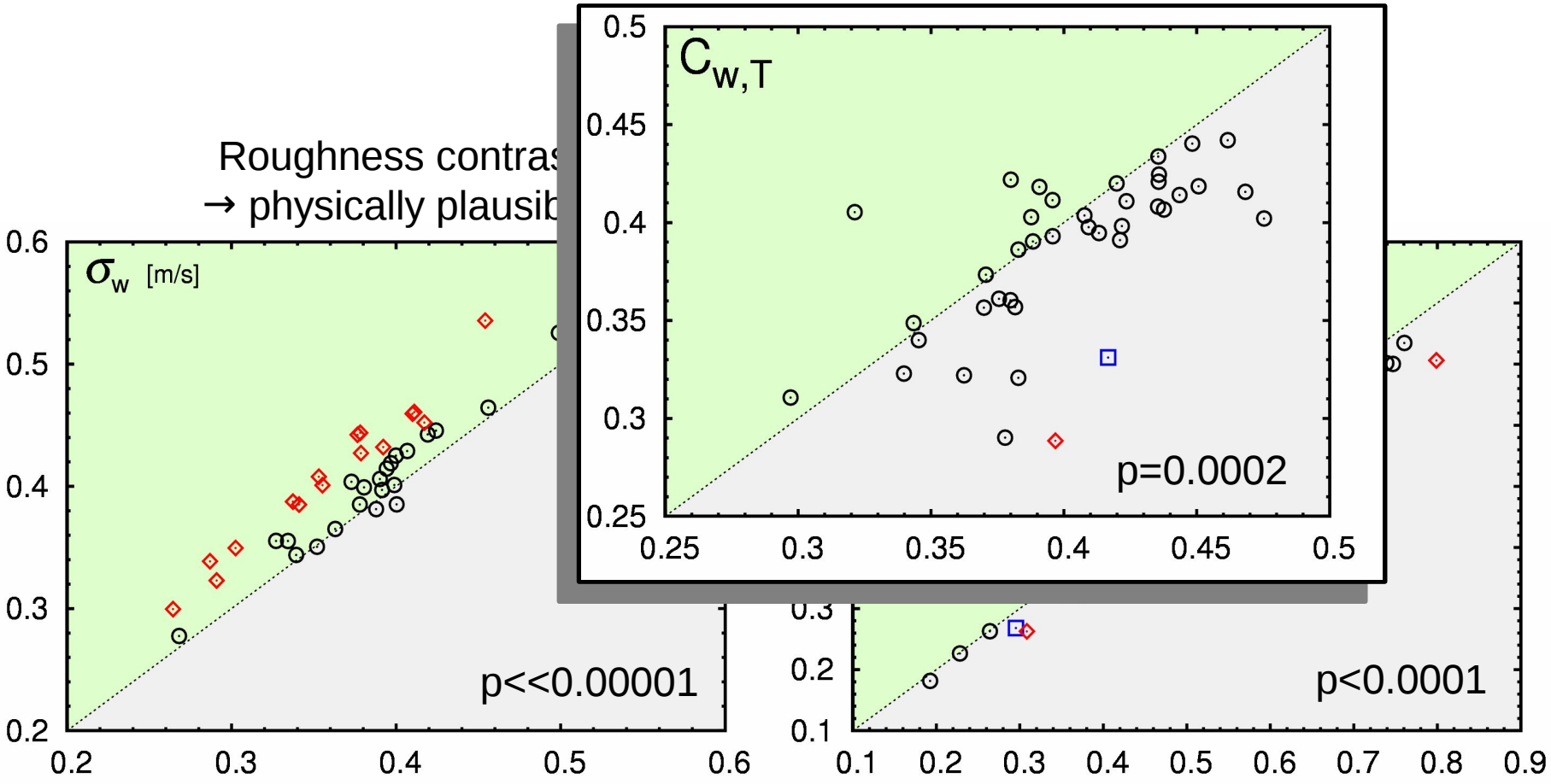


Results

$$\overline{w'T'} = \sigma_w \cdot \sigma_T \cdot C_{w,T}$$

In addition: scatter from correlation coefficient

Roughness contras
→ physically plausib



Summary

Eddy covariance method

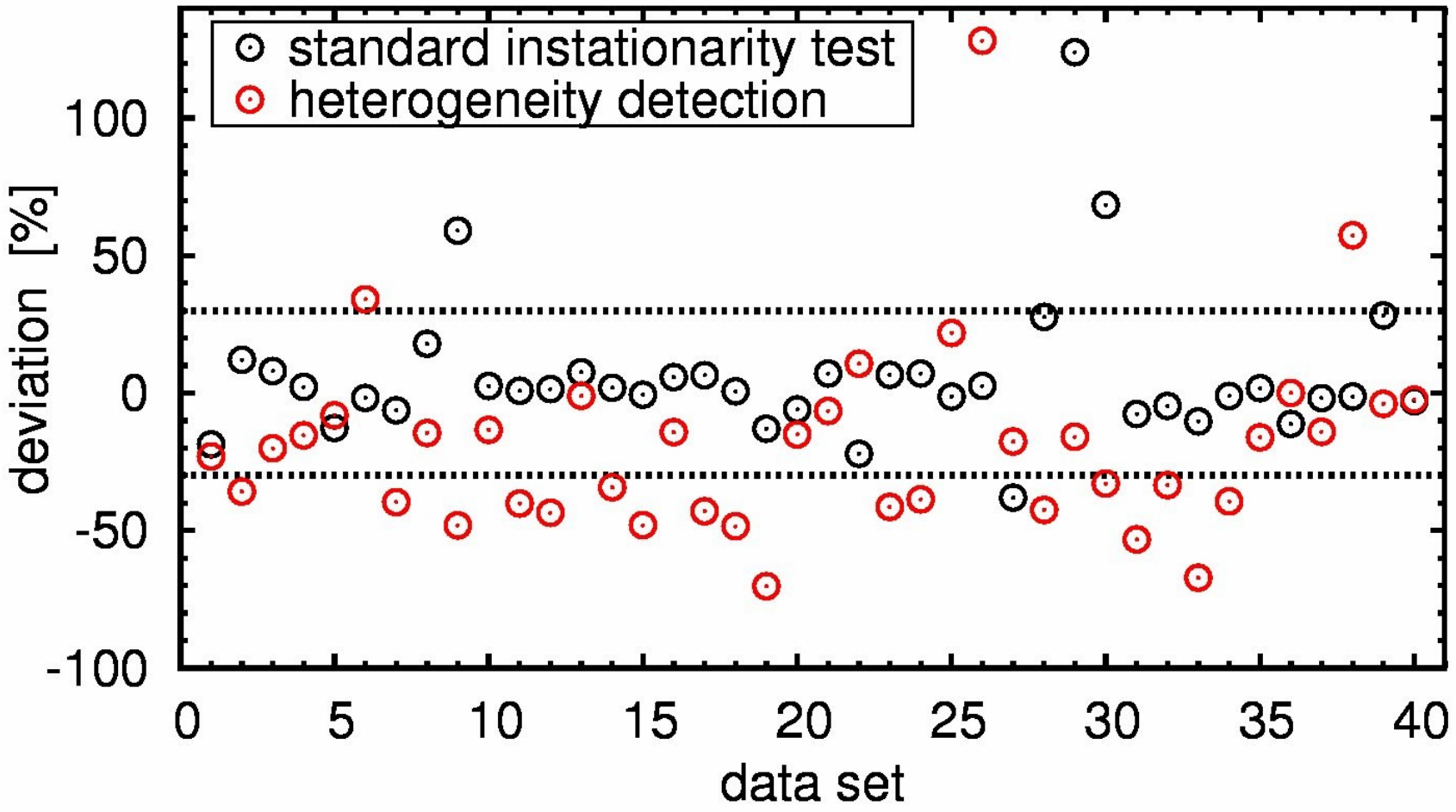
- Quality issue instationarity
- Here: surface heterogeneity + wind-direction fluctuations

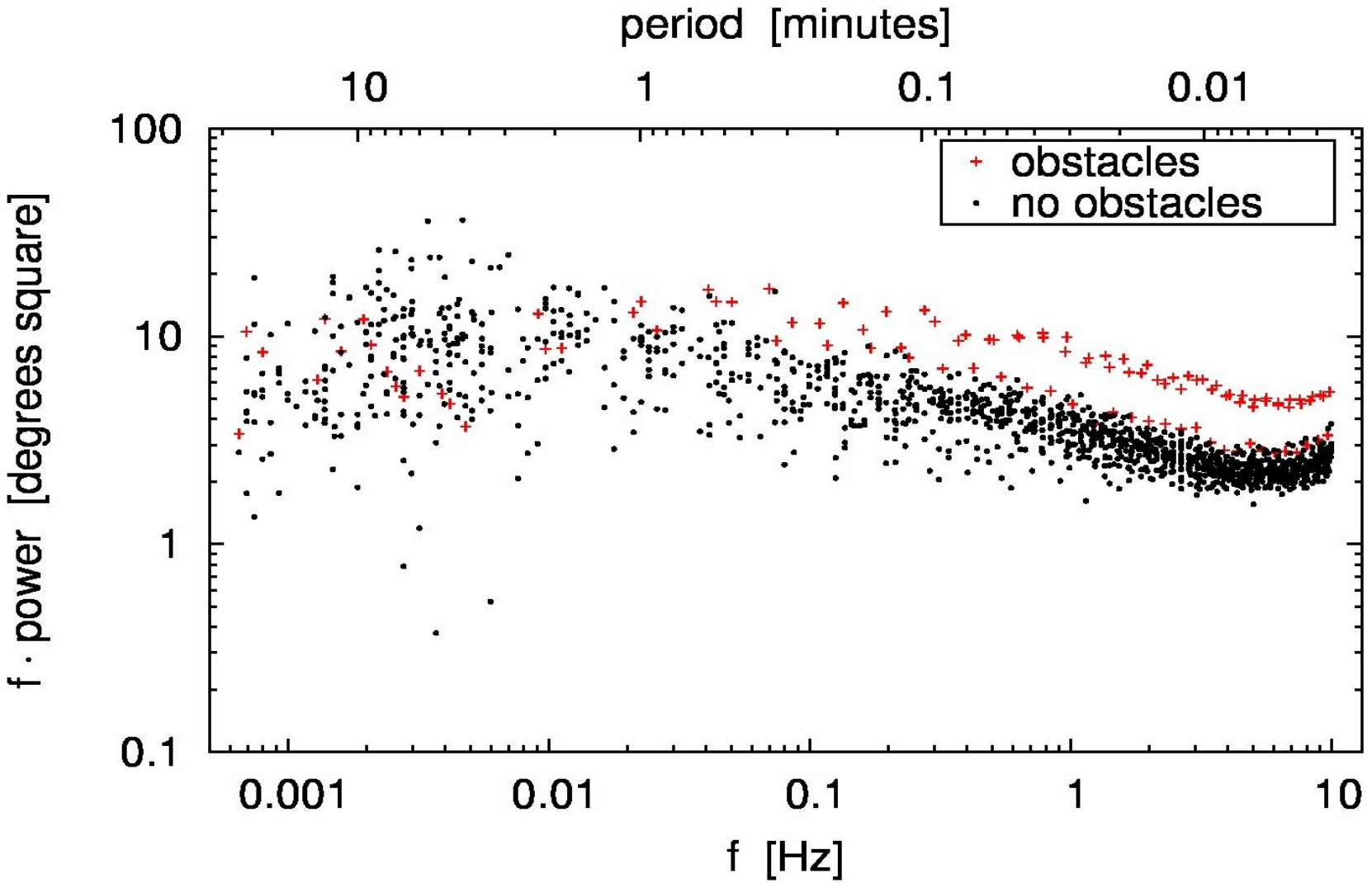
Detection scheme

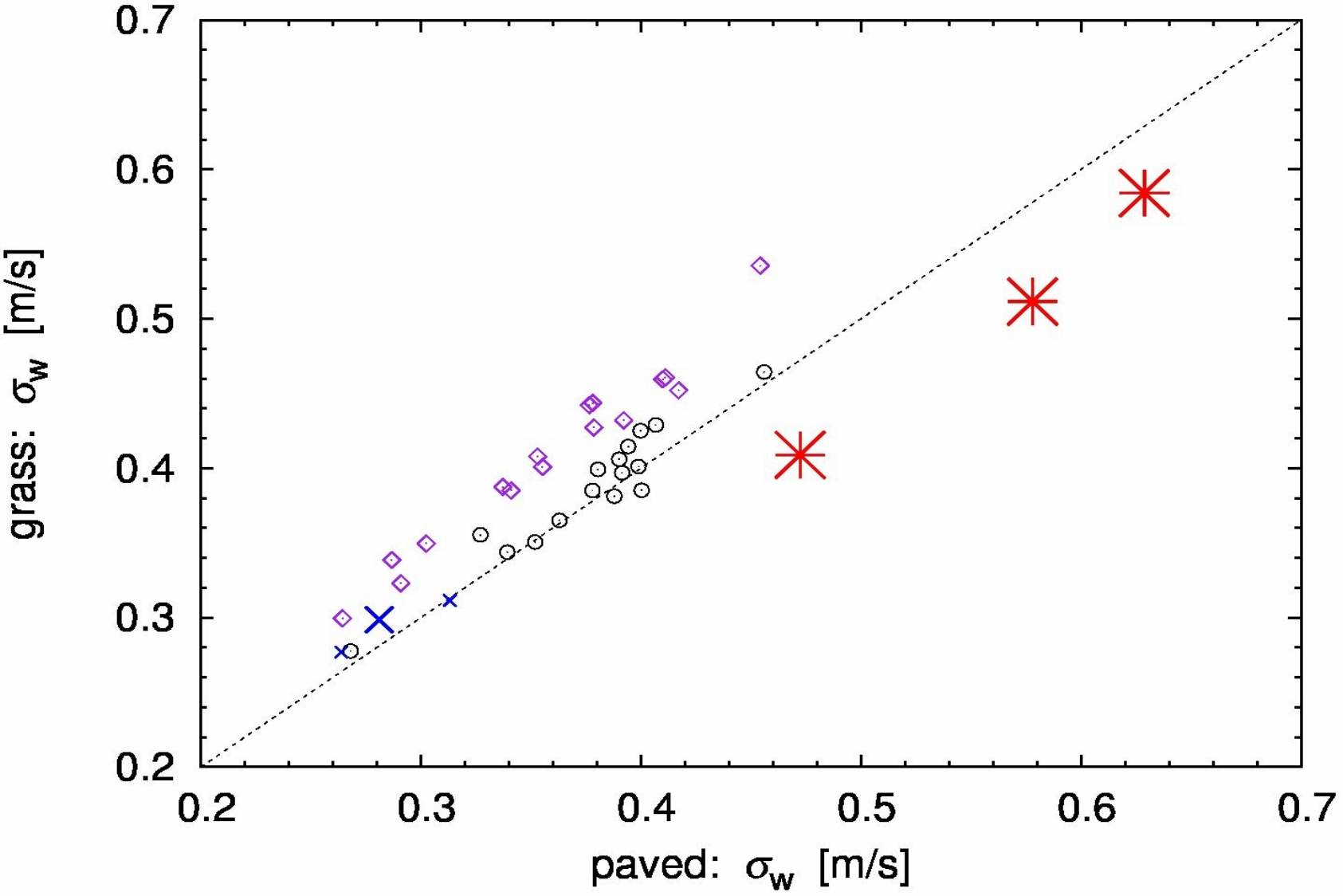
- Fetch-based binning
- Statistical inference
  - Uses random permutation
  - Accounts for auto-correlation

Test: paved surface ↔ grassland

- Results agree with physical setting
- Individual / pooled tests match
- But: correlation coefficients


standard instationarity test
heterogeneity detection
deviation [%]
100
50
0
-50
-100
0
5
10
15
20
25
30
35
40
data set


period [minutes]
10
1
0.1
0.01
100
10
1
0.1
f · power [degrees square]
obstacles
no obstacles
0.001
0.01
0.1
1
10
f [Hz]


0.7
0.6
0.5
0.4
0.3
0.2
0.2
0.3
0.4
0.5
0.6
0.7
grass: σ_w [m/s]
paved: σ_w [m/s]